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MARKUPS AND THE REAL EFFECTS OF VOLATILITY SHOCKS*

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This article studies the role of endogenous markups in the transmission of volatility shocks in real models. I design a variant of a small open economy model with volatility shocks and firm dynamics that gives rise to endogenous markups. I calibrate this model to match the business cycle facts in emerging economies and show that the impact of volatility shocks is substantially amplified if markups are endogenously time varying. Volatility shocks increase savings, due to precautionary motives, and markups, which act as a wedge that endogenously decreases real wages and labor supply with further negative aggregate dynamics that are absent in the models with constant markups.

1. INTRODUCTION

This article studies the channels behind the transmission of volatility shocks in real business cycle models. Specifically, I develop a real general equilibrium model for a small open economy with stochastic volatility and monopolistic competition, and use it to study the role of endogenously time-varying markups in the amplification and persistence of volatility shocks.

A “volatility shock” is a shock to the standard deviation of exogenous random variables. Even though the attention to volatility shocks as driving forces of the business cycle has recently increased because of the Great Moderation, the understanding of these shocks is still evolving.² The main reason for the limited understanding of volatility shocks is that these disturbances are of a very different nature compared to any other shock commonly used in the macroeconomics literature; volatility shocks do not affect the level of real or nominal innovations, but only the risk associated to future realizations.

The objective of this article is to contribute to the understanding of volatility shocks. I study the way time-varying markups, Frisch elasticity, and other model features affect the sign, magnitude, and persistence of the response of endogenous variables to volatility shocks in pure real models, that is, models without nominal frictions. The baseline model is a version of real business cycle small open economy model along the lines of Mendoza (1991) and Schmitt-Grohé and Uribe (2003), with GHH preferences, as in Greenwood et al. (1988), and stochastic volatility shocks. The baseline specification of the model assumes monopolistic competition in a setup that I borrow from Jaimovich (2007) and allows for entry and exit of firms, which

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² The Great Moderation refers to the period 1984–2007 during which the volatility of macroeconomic variables in the United States experienced a statistically significant drop compared to the pre-1984 sample. See McConnell and Perez-Quiros (2000) and Stock and Watson (2002). The “good luck” versus “good policy” debate was the one that intended to find the roots of the “Great Moderation.” Specifically, this debate inquires whether the decrease in aggregate volatility occurred due to an exogenous drop in the volatility of shocks, that is, the “good luck” scenario, or because policymakers had designed appropriate policy instruments to deal with exogenous disturbances, the “good policy” scenario.

gives rise to countercyclical markups as firm dynamics affect the degree of competition. Besides the firm dynamics, the model is an otherwise simple real business cycle small open economy model. This model, hence, allows us to study the role of endogenously time-varying markups without assuming price frictions or nominal disturbances and, consequently, allows us to isolate the effects of markups from those of nominal frictions, something that is impossible in New-Keynesian sticky prices models.

I find that endogenously time-varying markups induce a substantial amplification in the responses of endogenous variables to spread volatility shock because they exacerbate the response of real wages. Specifically, an increase in volatility triggers a consumption drop because of precautionary savings motives. Additionally, it negatively affects investment because agents reduce their exposure to financing through the more risky foreign debt. These two effects decrease the demand side of the economy. In the open economy, the trade balance improves, imports drop, and the domestic economy increases savings in foreign debt. Given the assumptions of monopolistic competitive firms, the drop in demand forces the exit of firms, which lowers the degree of competition and drives markups up. The increase in markups operates as inducing a drop in the measured total factor productivity (TFP) and decreases the real wage, inducing a drop in labor supply. The joint drop in labor and technology through the increase in markups induces an extra negative impact on output, which subsequently reinforces the drop in demand. This channel is absent without time-varying markups. This analysis is followed by a battery of robustness exercises and sensitivity analysis to provide further insights on the mechanisms behind the dynamics of the model. In a nutshell, I find that endogenously time-varying markups are critical to the transmission of volatility shocks in real models.

Fernández-Villaverde et al. (2011) study spread shocks and spread volatility shocks and show they have quantitatively important effects in the dynamics of emerging economies. The findings in this article reinforces theirs. I find that the impact of spread volatility shocks to output is twice as large when the markup dynamics are considered than in the model with fixed markups. When firms are subject to working capital constraints, the differences between the model with and without endogenous markups are even larger.

For a validation of the model, I study the dynamics of markups observed in the data for small open emerging economies. I show that markups exhibit a substantial variability, tend to be countercyclical, and have a positive correlation with volatility measures. In the real economy, a microfoundation for time-varying markups is likely to rely on firm dynamics. For this reason, I provide some stylized evidence on dynamics of firms in different countries using the database constructed by Bartelsman et al. (2009) that includes annual variables for entry and exit of firms at industry level for several open economies. I find evidence suggesting that the dynamic of firms is roughly in line with the implications of the model. To highlight even more the importance of endogenously time-varying markups, in the online appendix, I study a variant of the small open economy model with stochastic volatility in which markups change due to the existence of deep habits, as in Ravn et al. (2006). This setup assumes that there are no firm dynamics, and, as can be seen, the main results are robust to this alternative specification. In other words, even though there is stylized evidence validating the mechanisms in the model, the story of firm dynamics is not key for the quantitative results shown here.

This article is related to the literature that studies the role and importance of volatility shocks over the business cycle such as Bloom et al. (2007), Fernández-Villaverde and Rubio-Ramírez (2007), and Fernández-Villaverde et al. (2011). This literature has grown substantially during the last years and recently expanded to the study of the effect of changes in the volatility of technology, the volatility of fiscal and monetary policies, such as Fernández-Villaverde and Guerrón-Quintana (2015) and Fernández-Villaverde et al. (2010), as well as changes in the volatility of foreign interest rates in open economy models, as in Fernández-Villaverde et al. (2011), among several additional specifications. A recent review of this literature is in Fernández-Villaverde and Rubio-Ramírez (2013). However, all real models in this literature assume fixed markups, whereas endogenous markups have only been studied together with sticky prices in New Keynesian models.

There is substantial evidence supporting the time variation of markups over the business cycle. To my best knowledge, among the first references are Rotemberg and Woodford (1991) and Rotemberg and Woodford (1999), who find evidence supporting countercyclical markups; that is, they tend to increase together with output drops. However, there is a large list of references that study the impact of volatility shocks in models in which prices equal marginal costs, for instance, Fernández-Villaverde et al. (2011), Gruss and Mertens (2009), and Plante and Traum (2011). Given the evidence I present here, the results in these articles might substantially underestimate the impact of volatility shocks.

This article is also related to a growing literature studying the role of endogenous markups in the dynamics of general equilibrium models. For instance, Jaimovich (2007) develop models with endogenous markups to study firm dynamics and business cycle fluctuations. Additionally, Ravn et al. (2004a, 2004b, 2006) study a generalization of Abel's (1990) "Keeping up with the Joneses" external habit formation at the aggregate consumption level, to a framework in which this kind of habit formation occurs at the individual goods variety level and in this way affects markups endogenously. My article differs from those in this literature in that they do not consider the case of time-varying volatility and, hence, do not study how considering endogenous markups might affect the transmission channels following a volatility shock or the economics behind it.

As mentioned above, in models with sticky prices, some attention has been devoted to the interaction of volatility shocks and markups as in Basu and Bundick (2011) and Fernández-Villaverde and Guerrón-Quintana (2015). The contribution of my article is that I study this interaction in a pure real model. Hence, this article contributes to help disentangling the role of time-varying markups from the one of sticky prices in the amplification of volatility shocks.³

The remainder of the article goes as follows: In Section 2, I present the baseline real business cycle model with spread stochastic volatility and firm dynamics. Section 3 discusses the empirical strategy I follow to take this model to the data. Section 4 studies the dynamic behavior of endogenous variables after volatility shocks and provides a sensitivity analysis. Section 5 extends the analysis to an economy with working capital constraints. In Section 6, I study the dynamics of markups over the business cycle in small open economies in order to provide evidence of their substantial variability and their comovement with output. Finally, Section 7 concludes and provides a discussion of the potential implications of the main result.⁴

2. A REAL MODEL WITH ENDOGENOUS MARKUPS

The baseline model in this article is an extension of the simple small open economy real business cycle model, as in Mendoza (1991), including firm dynamics, as in Jaimovich and Floetotto (2008), and shocks to the volatility of spreads, as in Fernández-Villaverde et al. (2011).

Households have access to international asset markets where they trade a noncontingent asset under full commitment. Besides foreign debt issuance, households consume a unique final good, supply labor, and accumulate capital. On the other hand, I assume firms operate in a

³ Usually, sticky prices are considered for a variety of macroeconomic questions because they are able to generate time-varying markups. However, sticky prices are not the only reason why markups may change endogenously. Moreover, there is a large controversy on the speed of price adjustments as standard macroeconomic estimates differ from microestimates. The speed of price adjustment consequently affects markups. For these reasons it is important to understand the role of markups in economies without nominal frictions.

⁴ Additional exercises are available in an online appendix. In particular, the appendix studies the transmission of volatility shocks in models with deep habits following Ravn et al. (2004a, 2004b, 2006). Deep habits are an alternative way to induce endogenous markups in real models. I show that endogenous markups in this setup have also amplification power similar to the one in the model with firm dynamics. This allows me to provide a more general result about the role of endogenous markups in the transmission of volatility shocks in the sense that the amplification that endogenous markups generate is observed regardless of the setup that gives rise to time-varying markups. Additional exercises in the online appendix include the impact of different sizes of volatility shocks, the role of capital adjustment costs, and the importance of interest rate debt elasticity.

monopolistic competitive market and produce intermediate differentiated goods. Given this assumption, firms have monopolistic power that allows them to set prices above their marginal costs. Additionally, there is a final good producer that buys intermediate inputs to produce the final good that can be used for consumption, investment, or international trade. I now turn to a detailed description of the economic environment.

2.1. The Households. Assume the economy is populated by a large number of identical households that maximize the present discounted value of future expected utility streams given by the following expression:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t u(C_t, H_t),$$

where β denotes a time-invariant discount factor, C_t denotes final consumption, and H_t denotes hours worked. Households face a sequence of budget constraints,

$$\frac{D_t}{R_t} = D_{t-1} - w_t H_t - r_t^k K_t + C_t + I_t - \Pi_t.$$

Here, D_t denotes noncontingent debt issued in international asset markets. Households rent labor and capital services at competitive prices, w_t and r_t^k . Additionally, households own the firms and get any profits derived from their operation, Π_t . Foreign debt is also subject to a No-Ponzi game constraint. I_t denotes investment and the law of motion of capital is given by

$$K_{t+1} = (1 - \delta)K_t + \Phi(I_t, I_{t-1})I_t,$$

where δ denotes a constant depreciation rate and $\Phi(I_t, I_{t-1})$ is an adjustment cost on investment.

2.2. Firms and Market Structure. This article considers an economy with a single final good that can be consumed, used for investment purposes, or traded in the world market. The final good is produced by a competitive firm that combines differentiated inputs using a constant returns to scale technology given by

$$(1) \quad Y_t = \left(\int_0^1 Q_t(j)^\omega dj \right)^{\frac{1}{\omega}}.$$

Here, Y_t denotes the production of the final good and $Q_t(j)$ denotes input j used in production at period t . This $Q_t(j)$ is the output from industry j , and $\omega \in (0, 1)$ regulates the elasticity of substitution between inputs. Specifically, $1/(1 - \omega)$ is the elasticity of substitution between inputs produced by any two different sectors. Note that we use an infinite number of inputs to produce Y_t , which means that the model assumes a continuum of industries.

Additionally, each $Q_t(j)$ is produced by combining a finite number of intermediate inputs, denoted by $x_t(j, i)$, each of which is ultimately produced by combining labor and capital with a Cobb–Douglas technology. Hence, each industry has a finite number of firms operating in it, denoted by N_t . Output in industry j is given by

$$Q_t(j) = N_t^{\frac{\tau-1}{\tau}} \left[\sum_{i=1}^{N_t} x_t(j, i)^\tau \right]^{\frac{1}{\tau}},$$

where $0 < \tau < 1$ regulates the elasticity of substitution between inputs i , which is given by $1/(1 - \tau)$. Here, $x_t(j, i)$ denotes the output of firm i used in industry j . Each firm produces differentiated goods. Hence, firms have monopolistic power and are able to set prices.

Additionally, firms hire labor and capital in competitive factor markets that are combined using a Cobb–Douglas technology given by

$$(2) \quad x_t(j, i) = \exp(a_t) k_t(j, i)^\alpha h_t(j, i)^{1-\alpha} - \phi.$$

Here, a_t is a common stationary technology shock and ϕ denotes overhead costs. $k_t(j, i)$ and $h_t(j, i)$ are capital and labor services rented by firm i in industry j , and α denotes the capital share.

Under these assumptions, the demand and the price of industrial goods are given by

$$(3) \quad Q_t(j) = \left[\frac{p_t(j)}{P_t} \right]^{\frac{1}{\omega-1}} Y_t,$$

where $p_t(j)$ is the price of input j , and

$$P_t = \left[\int_0^1 p_t(j)^{\frac{\omega}{\omega-1}} dj \right]^{\frac{\omega-1}{\omega}}$$

is the price of the final good. Additionally, the demand and prices for intermediate inputs are given by

$$(4) \quad x_t(j, i) = \left[\frac{p_t(j, i)}{p_t(j)} \right]^{\frac{1}{\tau-1}} \frac{Q_t(j)}{N_t},$$

where $p_t(j, i)$ is the price of good i in industry j , and

$$p_t(j) = N_t^{\frac{1}{\tau}-1} \left[\sum_{i=1}^{N_t} p_t(j, i)^{\frac{\tau}{\tau-1}} dj \right]^{\frac{\tau-1}{\tau}}.$$

As usual, markups are defined as price over marginal costs,

$$\mu(N_t) = \frac{p_t(i, j)}{MC_t(i, j)}.$$

In a symmetric equilibrium $x_t(j, i) = x_t$, $k_t(i, j) = k_t$, $h_t(i, j) = h_t$, $p_t(i, j) = p_t(j) = P_t$, which is normalized to 1. Aggregate capital and hours are given by $K_t = N_t k_t$ and $H_t = N_t h_t$. We impose a zero profit condition in each sector for every period,

$$(5) \quad (\mu(N_t) - 1)x_t = \phi,$$

where $\mu(N_t)$ stands for the markup.⁵ Notice that, given the symmetric equilibrium, using Equations (3) and (4), it can be shown that $N_t x_t = Y_t$. Additionally, following Jaimovich and Floetotto (2008), the number of firms and a different expression for aggregate output can be found by combining (5) and (2):

$$(6) \quad N_t = \exp(a_t) K_t^\alpha H_t^{1-\alpha} \left[\frac{\mu(N_t) - 1}{\mu(N_t)\phi} \right],$$

⁵ From solving the problem of the intermediate input producer, it can be shown that μ_t is a function of N_t , $\mu(N_t) = \frac{(1-\omega)N_t - (\tau-\omega)}{\tau(1-\omega)N_t - (\tau-\omega)}$.

$$Y_t = \frac{\exp(a_t)}{\mu(N_t)} K_t^\alpha H_t^{1-\alpha}.$$

Notice that the TFP, the part of output not explained by labor and capital inputs, in this model is endogenous and can be defined as follows:

$$TFP_t = \frac{\exp(a_t)}{\mu(N_t)}.$$

Using the previous expressions, the rental rates of labor and capital can be expressed in familiar terms,

$$w_t = (1 - \alpha) \frac{Y_t}{H_t},$$

and

$$r_t^k = \alpha \frac{Y_t}{K_t}.$$

Ultimately, notice that in the symmetric equilibrium the solution to this model is very similar to the one of a standard real business cycle model with competitive firms. However, here we need to keep track of the number of firms and markups. In other words, Equation (6) is required to characterize the equilibrium. The online appendix presents the full set of equations that characterize the equilibrium of this model.

2.3. Stochastic Processes. I assume there are three driving forces in this economy, a shock to the level of technology, a shock to the level of spread, and a shock to the volatility of the spread. Technology follows an autoregressive process with stochastic volatility,

$$a_t = \rho_a a_{t-1} + \sigma_a \epsilon_{a,t}.$$

Interest rate on international debt is given by

$$R_t = R + \Psi(\hat{D}_t - D) + e^{\epsilon_t} - 1.$$

Here, R denotes the steady-state interest rate that is assumed constant.⁶ $\Psi(\hat{D}_t - D)$ denotes an endogenous component of the sovereign spread that also works as a inducing stability device. Additionally, in line with Garcia-Cicco et al. (2010), this term can be interpreted to capture the role of financial frictions. ϵ_t denotes a spread shock given by

$$\epsilon_t = \rho_\epsilon \epsilon_{t-1} + \sigma_\epsilon e^{v_{\epsilon,t}} \epsilon_{\epsilon,t},$$

where

$$v_{\epsilon,t} = \rho_{v,\epsilon} v_{\epsilon,t-1} + \sigma_{v,\epsilon} \eta_{\epsilon,t}.$$

Here, we assume that all stochastic processes are mean reverting. Additionally, $\epsilon_{a,t} \sim N(0, 1)$, $\epsilon_{\epsilon,t} \sim N(0, 1)$, and $\eta_{\epsilon,t} \sim N(0, 1)$.

⁶ In Fernández-Villaverde et al. (2011), the risk-free rate is assumed to follow a stochastic volatility model and the real rate is completely exogenous. They find, however, that risk-free rate shocks and the volatility shocks to the risk-free rate have a limited importance to explain the dynamics of emerging economies. The term in $\Psi(\hat{D}_t - D)$ is meant to capture the fact that some variability of real interest rates in emerging economies is due to endogenous sources; see Uribe and Yue (2006).

3. SOLUTION METHOD, FUNCTIONAL FORMS, AND CALIBRATION

As discussed in the “Introduction,” the main objective of this article is to study the transmission mechanisms behind the responses to volatility shocks in real models. It is still important to study these dynamics in an empirically plausible model, that is, a model whose dynamics can represent observed dynamics. Consequently, before studying the main results of the article, this section discusses some aspects of the empirical strategy, including the solution method, functional forms, and the calibration.

3.1. *Solution Method.* I use a third-order perturbation method in logarithms to approximate the policy functions around the nonstochastic steady state. As has been widely discussed in methodological references such as Aruoba et al. (2006) and also in Fernández-Villaverde et al. (2011), the perturbation method is a local solution method that makes use of the Taylor series expansion and might be applied for any desired order of approximation. A first-order perturbation in logarithms is equivalent to a log-linear approximation and, as we know, this solution is certainty equivalent. This means that any change in the volatilities of the innovations does not have effect in the policy functions, that is, agents do not respond to volatility changes up to first order. The approximation of second order captures a constant correction to the impact of volatility changes. Only for approximation of a third (or higher) order, changes in the volatility of stochastic processes appear in an autonomous way in the policy functions. This means that, in this case, agents respond directly to changes in volatilities even if all other shocks are zero. Hence, a third order of approximation is required to capture the first-order effect of volatility shocks.⁷

3.2. *Functional Forms.* I assume utility function is GHH, as in Greenwood et al. (1988),

$$u(C_t, H_t) = \frac{\left[C_t - \theta \frac{H_t^\eta}{\eta} \right]^{1-\gamma} - 1}{1-\gamma}.$$

Here η determines the Frisch elasticity that regulates the response of labor supply to wages, whereas γ determines the curvature of the utility function. θ in turn regulates the disutility of labor supply and does not affect the models dynamics but the steady-state level of labor supply.

One of the properties of GHH utility functions is that they eliminate the wealth effect on labor, and, hence, labor only responds to changes in the real wage. This is a convenient property of the utility function to match the dynamics observed in the data. In Subsection 4.3, I also consider the implications of the model when using a separable utility function.

I follow Fernández-Villaverde et al. (2011) for the functional form of the adjustment costs of capital,

$$\Phi(I_t, I_{t-1}) = 1 - \frac{\phi}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2,$$

where $\phi > 0$. In turn, I follow Aguiar and Gopinath (2007), Garcia-Cicco et al. (2010), and Seoane (2015a) for the functional form of the risk premium,

$$\Psi(\hat{D}_t - D) = \psi(e^{\hat{D}_t - D} - 1),$$

where ψ determines the elasticity of the interest rate to debt. Notice that the risk premium depends on \hat{D}_t , which is the aggregate level of debt and it is not internalized by the households.

⁷ For details on the solution method, the reader is referred to the aforementioned references, Aruoba et al. (2006) and Fernández-Villaverde et al. (2011).

TABLE 1
CALIBRATED PARAMETERS

Parameters	Description	Value
α	Capital share	0.32
δ	Quarterly depreciation rate	0.024
μ	Steady-state markup	1.3
γ	Risk aversion coefficient	2
η	Frisch elasticity coefficient	1.6
ρ_a	Persistence TFP shock	0.857
ω	Technology parameter	0.001
τ	Technology parameter	0.949

NOTES: Parameters are fixed to values in existing literature. The main text explains the details on the sources for each of them.

3.3. Calibration. Here, I set the deep parameters affecting preferences and technology to standard values in the small open economy literature and calibrate the remaining parameters to target a set of moments observed in the data.

Table 1 presents the parameters fixed to standard values. α denotes the capital share, and it is fixed to 0.32 as is common in the real business cycle literature. To set the depreciation rate, δ , I follow Fernández-Villaverde et al. (2011), who assume this parameter is equal to 0.008 for a monthly frequency specified model. Given that the model in this article is specified at quarterly frequency, I fix it to 0.024, that is, a quarterly depreciation rate of 2.4%. I fix $\rho_a = 0.857$ in line with the parameterization chosen in Fernández-Villaverde et al. (2011). μ denotes the steady-state level of markups, whereas ω and τ determine the intrasectoral and intersectoral elasticities of substitution, respectively. Jaimovich and Floetotto (2008) calibrate τ by using U.S. firm-level data. In their paper, the numerical exercises are done using a linear approximation, which gives up to a relationship between firm dynamics and output dynamics that identifies τ conditional on the average markup. In a third-order approximation, we should pin it down using the full set of moment conditions, but given that I do not have as such rich data set including firm dynamics at quarterly frequency for the emerging economies I consider in this article, I fixed those parameters to their calibrated values, and I study the sensitivity of the results to different values.⁸ It is important to emphasize, as do Jaimovich and Floetotto (2008), that the value of ω does not affect the dynamics of the model. In turn, η and γ are set in line with several papers in the small open economy literature. θ is fixed such that the model generates $H = 0.3$ in steady state, as in Jaimovich and Floetotto (2008).

Table 2 presents the targets for the matching moments empirical strategy. Additionally, the table presents the theoretical moments implied by the baseline economy and by the economy with working capital constraints (that is explained in Section 5).⁹ As seen in the table, the models are able to accommodate to match the main features of emerging economies. The existence of time-varying markups is also helpful for a good performance of the model. A negative shock that affects negatively output and makes the economy poorer induces a fall in consumption and a large investment drop given the increase in markups. The amplification from the markups dynamics helps the model to match moments that are hard to match with baseline Dynamic Stochastic General Equilibrium models such as the countercyclical trade balance to output ratio.¹⁰

⁸ I find that the results in the article do not depend on this specific aspect of the calibration; the results are reported in the online appendix.

⁹ Moments in the model are computed theoretically as in Andreasen et al. (2013).

¹⁰ The model generates an interest rate volatility slightly larger than the one in the data. However, it is important to highlight that the numbers generated by the model and shown in the table are plausible. In particular, there is a wide dispersion in the volatility of interest rates across countries and across samples. For instance, average volatility of interest rates in the case of Argentina is in the order of 3.9%, quite close to the one generated by the model with working capital constraints.

TABLE 2
MOMENTS TO MATCH

Parameters	Targets	Baseline Model	Model with WCC
$n\bar{x}y_t$	0.01	0.012	0.01
\bar{R}_t	1.03	1.03	1.03
$\sigma(y_t)$	5.7	5.3	5.5
$\sigma(c_t)$	6.1	8.8	7.7
$\sigma(i_t)$	16.5	15.9	15.4
$\sigma(nxy_t)$	4.2	7	4.2
$\sigma(R_t)$	1.97	6.3	4.6
$\rho(y_t, nxy_t)$	-23.2	-8.98	-17.9
$\rho(nxy_t, nxy_{t-1})$	79.2	83.6	86.1
$\rho(R_t, R_{t-1})$	85.7	78.4	77.8

NOTES: Average targets for Argentina, Brazil, Ecuador, and Venezuela. Data are logged and linearly detrended at quarterly frequency. Moments are in percentage terms. y_t , c_t , i_t , and nxy_t denote (respectively) output, consumption, investment, and net exports to output ratio. R_t is the real interest rate. \bar{x} denotes the mean of x , $\sigma(\cdot)$ denotes standard deviations, and $\rho(\cdot, \cdot)$ denote correlations, in percentage terms. WCC: Working Capital Constraint.

TABLE 3
MATCHING MOMENTS PARAMETERS

Parameters	Description	Baseline	WCC
D	Steady-state debt level	0.451	0.30
R	Steady-state interest rate	1.039	1.04
ϕ_k	Adjustment costs of capital coefficient	17.4	12.3
ψ	Elasticity of interest rate to external debt	0.077	0.06
Θ	Coefficient of the working capital constraint	—	0.29
σ_a	Average volatility of technology shock	1e-7	0.0001
ρ_e	Persistence of spread shock	0.79	0.79
σ_e	Average volatility of spread shock	0.033	0.026
$\rho_{v,e}$	Persistence of stochastic volatility shock	0.999	0.999
$\sigma_{v,e}$	Standard dev. of stochastic volatility shock	0.021	0.016

NOTES: These parameters are calibrated in order to match the moments in Table 2. The main text explains the details for this procedure. WCC: Working Capital Constraint.

R denotes the steady-state interest rate, and D is the steady-state foreign debt level. In a linear approximation, I would calibrate these objects such that steady-state values match data averages; in the nonlinear approach, I set them such that the mean of the ergodic distribution of interest rate and debt are in line with $1.13^{1/4}$, about 1.03 at quarterly levels, and the net exports to output ratio of 1%.¹¹ The remainder of the targets are second-order moments that describe the main features of emerging economies. Table 3 presents the calibrated parameters. As seen in the table, the calibrations for both models are similar. In both cases they imply a high persistence of the volatility shock with a mild persistence of level shock. Technology shock volatility is rather small, although minor differences are shown in other dimensions such as the steady-state level of debt and the adjustment costs of capital. The working capital constraint coefficient on the order of 30% of the wage bill is plausible, although smaller than the ones usually assumed by existing literature such as Mendoza and Yue (2012), Neumeyer and Perri (2005), and Uribe and Yue (2006).

¹¹ The real interest rate target is in line with the ones experienced by the countries in our sample over the recent period. This number is also in line with the average real interest rate for these countries for a similar sample in Fernández-Villaverde et al. (2011).

TABLE 4
NONTARGETED MOMENTS

Parameters	Data (Averages)	Baseline Model	Model WCC
$\rho(r_t, y_t)$	-37.9	-15.4	-36.9
$\rho(r_t, c_t)$	-41.2	-78.7	-80.8
$\rho(r_t, i_t)$	-36.5	-69.2	-68.8
$\rho(r_t, nxy_t)$	29.1	93.9	91.7
$\rho(y_t, c_t)$	72.1	64.6	80.6
$\rho(y_t, i_t)$	79	32.1	50.7
$\rho(c_t, nxy_t)$	-76	-79.8	-69.4
$\rho(i_t, nxy_t)$	-60.3	-66.5	-68.0
$\rho(y_t, y_{t-1})$	68.7	99.8	98.5
$\rho(c_t, c_{t-1})$	83.6	88	86.3
$\rho(i_t, i_{t-1})$	87.9	97.9	97.7

NOTES: Average moments for Argentina, Brazil, Ecuador, and Venezuela. Data are logged and linearly detrended at quarterly frequency. Moments are in percentage terms. r_t denotes the log linearly detrended real interest rate computed by using three months T-bill rate plus Emerging Markets Bond Index+ net of expected inflation. $\rho(\cdot, \cdot)$ denotes correlations. WCC: Working Capital Constraint.

4. RESULTS

Results are organized as follows: First, I show the performance of the model in the nontargeted moments. Second, I study the dynamics of the model following a volatility shock, and, finally, I study various sensitivity exercises to identify the role of different assumptions in the implied dynamics.

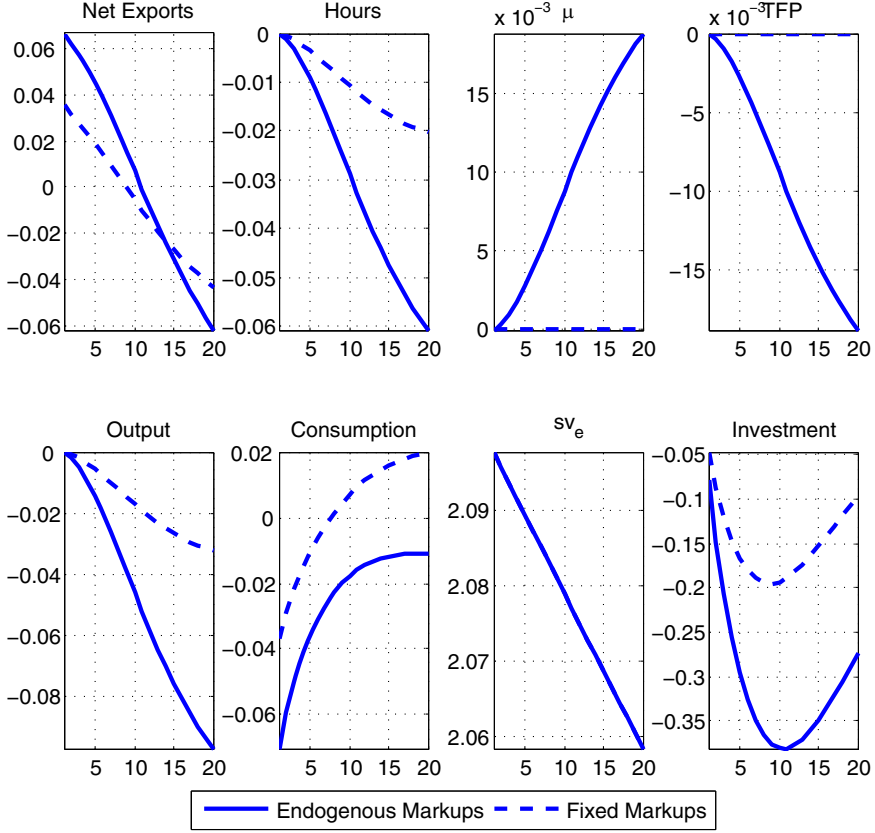
4.1. Nontargeted Moments. Table 4 presents several nontargeted moments in the data and the ones implied by the model.

Overall, it seems the model is able to generate plausible dynamics for the interest rate and also seems to match fairly well the other moments of interest, except that it overestimates the autocorrelation of output. As can be seen, both models are able to capture the negative correlation between interest rate and consumption and interest rate and investment as well as the positive correlation with net exports to output ratio. Moreover, the degree of variability and the comovement between variables in both models are of a similar order of magnitude as those observed in the data. Regarding the dynamics of markups, as can be seen, the model can generate volatile and countercyclical markups. As described in the model, the markups' correlation with output is hardwired in the firm's dynamics assumption, giving rise to the strong negative correlation.

In sum, even though interest rates moments are nontargeted, the moments implied by the models are in line with stylized facts observed in the data, suggesting that the economies studied in this section are likely to generate plausible dynamics for the variables of interest.

4.2. Dynamics. Figure 1 presents the impulse response functions of endogenous variables to 1 standard deviation volatility shock, both for the model with monopolistic competition, denoted by the solid line labeled as "Endogenous Markups" and the model with competitive markets, denoted by the dashed line labeled as "Fixed Markups." The economy with fixed markups is a simplified version of the baseline economy; specifically it is the case in which markups are always fixed to 1. It can be shown that, in this case, the number of firms does not matter and can be normalized to 1. Other aspects of the economy remain the same; specifically the remainder of the calibration does not change.

As seen in the figure, the mechanism that generates time-varying markups substantially amplifies the dynamics of endogenous variables following a shock to the volatility of spreads. The economics of these dynamics are as follows: After a volatility shock, the precautionary savings motive induces a drop in consumption, and, as a counterpart, households save more



NOTES: This figure plots the response to a 1 std shock to the volatility of spread shock. The impulse response function for variable x is plotted as $100 \times \hat{x}$, where \hat{x} denotes log deviations. Impulse responses are constructed using the generalized impulse response function.

FIGURE 1

IMPULSE RESPONSES TO A VOLATILITY SHOCK [COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

using foreign debt; that is, households decrease their liabilities or increase their assets against the rest of the world, which also implies that net exports improve.

The behavior of aggregate demand translates in a drop of production of the final good, inducing the exit of firms that produce inputs for intermediate goods. When firms exit, the degree of competition falls and markups rise. Recall that as markups increase, wages and the return to capital fall accordingly to these expressions:

$$w_t = (1 - \alpha) \frac{\exp(a_t)}{\mu(N_t)} K_t^\alpha H_t^{1-\alpha},$$

$$r_t^k = \alpha \frac{\exp(a_t)}{\mu(N_t)} K_t^{\alpha-1} H_t^{1-\alpha}.$$

Hence, real wages also decrease. Given GHH utility function, labor supply also decreases. On the other hand, the response of r_t^k exacerbates investment fall. Additionally, in our formulation the TFP is endogenous,

$$TFP_t = \frac{\exp(a_t)}{\mu(N_t)};$$

TABLE 5
MARKUPS

Parameters	Baseline Model	Model WCC
$\sigma(\mu_t)$	1	1
$\rho(\mu_t, y_t)$	-99.6	-99.8
$\rho(\mu_t, R_t)$	15.5	37.2

NOTES: $\sigma(\cdot)$ denotes standard deviations and $\rho(\cdot, \cdot)$ denotes correlations. In percentage terms. WCC: Working Capital Constraint.

hence, for the model with monopolistic competition, volatility shocks have a first-order effect on the TFP, even when the exogenous component of technology is fixed at its ergodic mean. Note that, even though this exercise isolates the impact of volatility shock alone, we can highlight some interesting points. First, note that the dynamics of markups and output after a volatility shock is roughly in line with the evidence presented in Table 5 because, as can be seen in the figure, markups are countercyclical and highly volatile after a volatility shock. Second, from this picture, we can also infer that volatility shocks contribute to generate a consumption dynamics more volatile than output; here, in particular, consumption response on impact is much stronger than the output one.

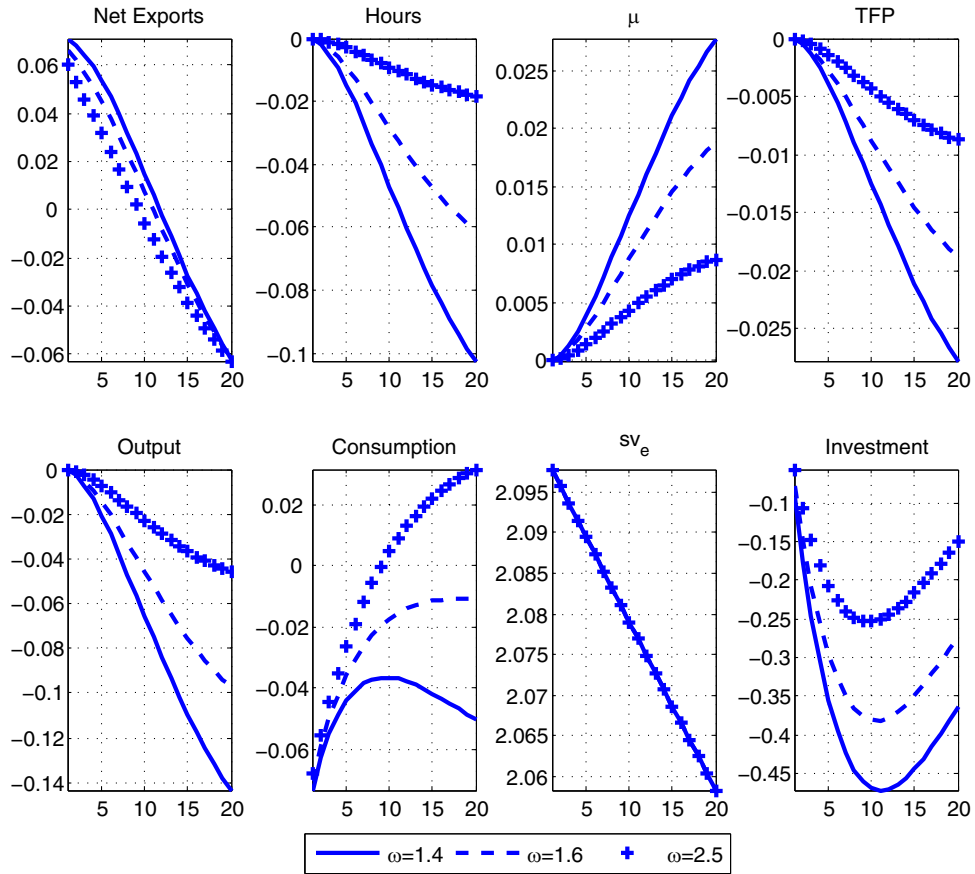
In summary, the dynamics of the economy with time-varying markups are amplified compared to the one with fixed markups. The reason is that in the case of monopolistic competition, when aggregate demand falls, the number of firms operating in each industry falls too, the markets become less competitive, and, hence, the firms that stay are able to charge larger markups. This is absent in the case of perfect competition. Moreover, if markups do not change, the only way to affect wages and the return to capital is through the level of factors used in production, leading to substantially smaller effects than in the case of endogenously time-varying markups.

4.3. Robustness Analysis. I implement two robustness exercises to provide further insights on the mechanisms behind the dynamics of the model. First, I study to what extent the main results depend on the Frisch elasticity given that Fernández-Villaverde et al. (2011) point out that the response of labor supply to volatility shocks is of major importance. Finally, it is a well-known feature of GHH preferences that they eliminate the wealth effect and make labor supply only dependent on the real wage. For this reason, I study whether the dynamics are affected if we assume separability in the utility function.¹²

4.3.1. The role of the Frisch elasticity. As discussed earlier, the Frisch elasticity determines the response of labor supply to wages and through this channel regulates the response of labor to a volatility shock. In a model with GHH preferences, the Frisch elasticity is $\frac{1}{\eta-1}$. For the baseline calibration this equals 1.66, which implies that if the wage changes in 1%, the labor supply changes in 1.66%. This level of Frisch elasticity is standard in small open economy models, as was discussed when introducing the baseline calibration.

This section considers two additional calibrations for the Frisch elasticity, a high Frisch elasticity of 2.5 ($\omega = 1.4$) and a low Frisch elasticity of 0.7 ($\omega = 2.5$). Figure 2 presents the impulse responses functions for each of these cases. As seen in the figure, the Frisch elasticity has a major importance on the size of the response of endogenous variables to a volatility shock. However, it does not affect the qualitative dynamics. As seen in the figure, a large Frisch elasticity of 2.5 amplifies the dynamics compared to low Frisch elasticity cases. The economic intuition behind this finding is that when a volatility shock hits the economy, the high Frisch elasticity implies that for a drop in the real wage of 1% the labor supply falls 2.5%. Given that labor supply is more responsive and this negatively affects

¹² The online appendix presents results for other exercises of interest. Specifically, the role of adjustment costs of capital and debt interest rate debt elasticity are studied.



NOTES: This figure plots the response to a 1 std shock to the volatility of spread shock. The impulse response function for variable x is plotted as $100 \times \hat{x}$, where \hat{x} denotes the log deviations. Impulse responses are constructed using the generalized impulse response function.

FIGURE 2

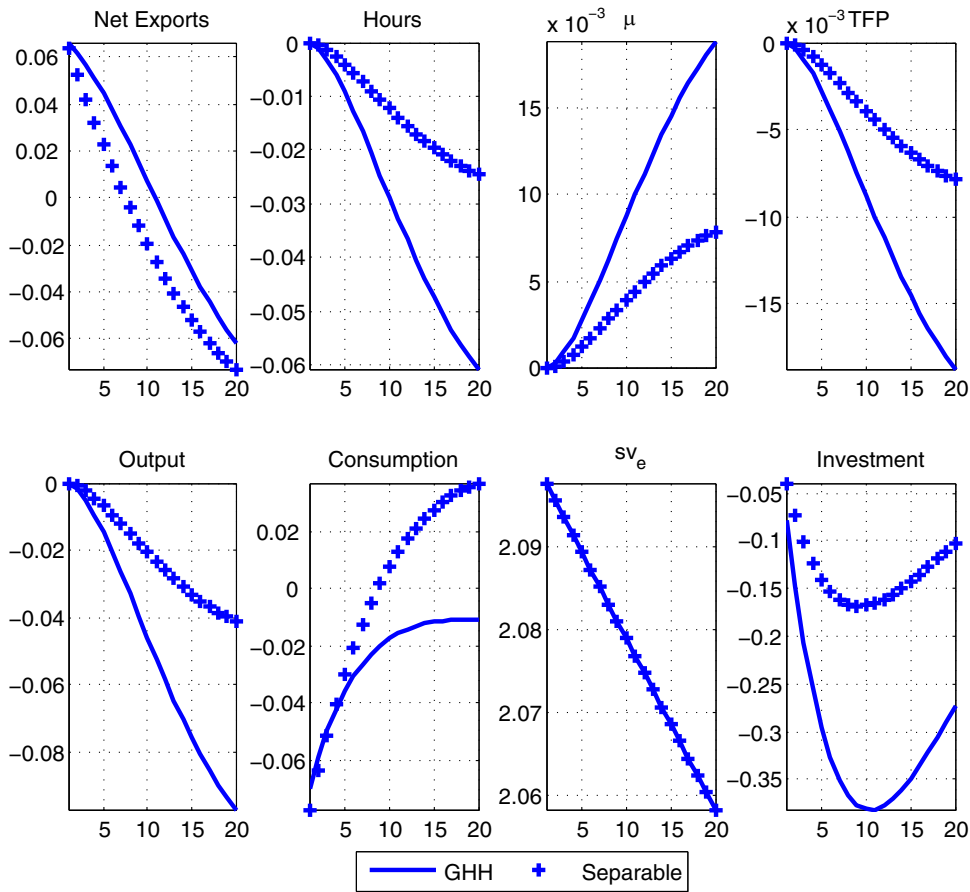
IMPULSE RESPONSES TO A VOLATILITY SHOCK [COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

the agents' labor income, incentives to save are higher. Moreover, given a larger response of labor supply, the marginal product of capital also responds in a stronger way affecting the incentives to invest. This explains the amplification of the dynamics of investment and consumption. In the same way as for the baseline calibration, the impact on aggregate demand affects the number of firms, which increases markups, decreases the TFP, and amplifies the dynamics.

4.3.2. Separable preferences. A key element of my analysis is the GHH preferences. It is well known that this type of preference eliminates the wealth effect in the response of hours to any disturbance.

To capture the stylized facts of volatility shocks, a small or nil wealth effect is an important feature because when volatility increases, the wealth decreases, and this might have a positive effect in labor supply, which is at odds with the data. In this section, I compare the responses under GHH and the responses under the following separable utility function:

$$u(C_t, H_t) = \frac{C_t^{1-\sigma} - 1}{1-\sigma} + \theta \frac{(1-H)^{1-\eta} - 1}{1-\eta}.$$



NOTES: This figure plots the response to a 1 std shock to the volatility of spread shock. The impulse response function for variable x is plotted as $100 \times \hat{x}$, where \hat{x} denotes the log deviations. Impulse responses are constructed using the generalized impulse response function.

FIGURE 3

IMPULSE RESPONSES TO A VOLATILITY SHOCK [COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

This utility function is the one in Ravn et al. (2006). I calibrate it such that it is comparable to the one in the baseline model. I assume a Frisch elasticity of 1.66, as in the benchmark case, and θ is calibrated to match the $H = 0.3$ while $\sigma = 2$. Figure 3 presents the impulse responses for the baseline economy with GHH together with the ones assuming separability.

Note interestingly that wealth effects for labor supply plays a role; with separability, labor supply does not adjust as in the GHH case. However, a substitution effect still dominates as labor falls. Consumption drop is much less persistent and given that labor does not adjust much, output and investment response is also milder. Second, incentives to save are smaller too, and the amplification of endogenous markups is also smaller than under GHH given that the response of labor increases output, and this represents a pressure to decrease savings instead of increasing it.

In sum, from this section, it is clear that the response of labor, in terms of both elasticities and wealth effects is central to replicate the dynamics observed in the data.

4.4. A Model with Deep Habit. A natural question at this point is whether the dynamics of the model, implying amplification of aggregate variables and markups, is exclusive of a model with firm entry and exit, or it could be generated by other ways of modeling endogenous markups. The online appendix presents a version of small open economy model with deep

habits as in Ravn et al. (2006). As discussed in Ravn et al. (2006), habit formation at each variety level gives rise to endogenous countercyclical markups. It can be seen in the appendix that for a plausible calibration of the model, the model with endogenous markups due to deep habits amplifies the dynamics after a volatility shock. That is, the economy with time-varying markups exhibits substantially larger variability than the model with fixed markups, regardless of this behavior being generated by deep habits or by firm dynamics. This result is important in the sense that it highlights that the results of this article do not depend on firms dynamics, but on the existence of endogenously time-varying markups.

5. WORKING CAPITAL CONSTRAINTS

The previous specification does not include a working capital constraint. However, several authors emphasize this channel as a source of amplification for emerging market fluctuations. Suppose that firms have to pay a fraction, Θ , of the wage bill in advance, that is before production takes place, while keeping the rest of the model unchanged. To do so, firms have to borrow funds at a market rate. This assumption only affects the market wage,

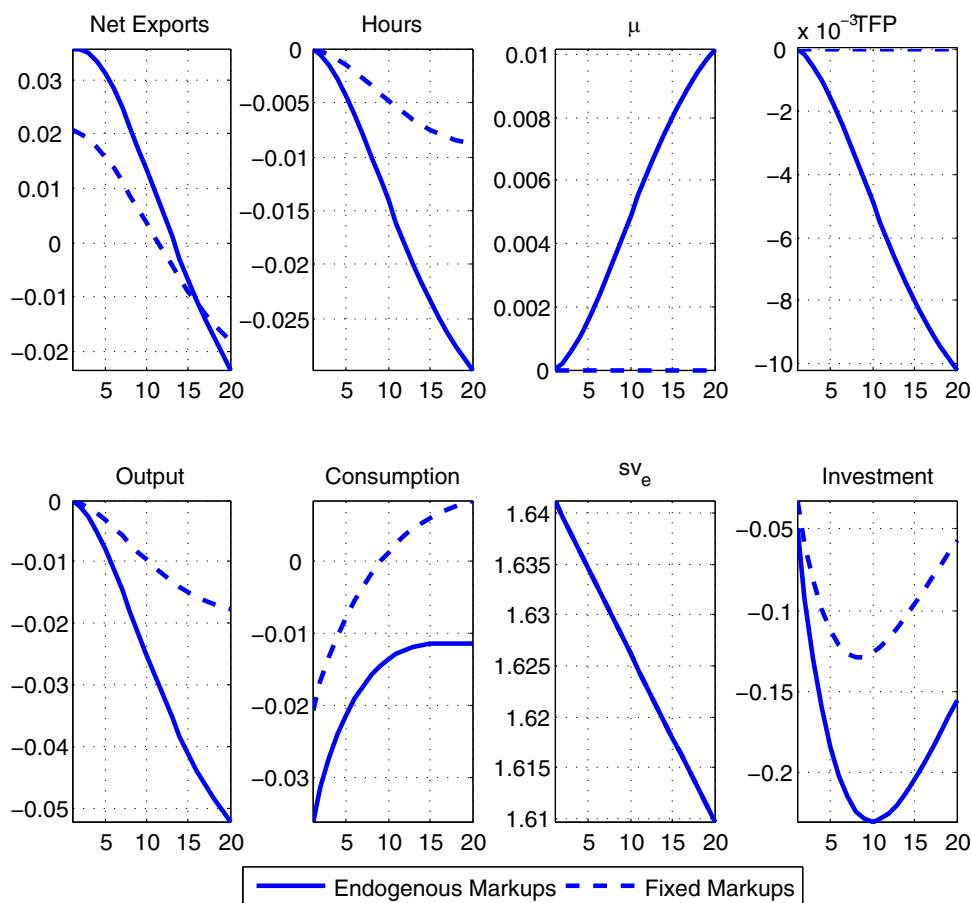
$$w_t = \frac{(1 - \alpha)}{(1 + \Theta(R_t - 1))} \frac{Y_t}{H_t}.$$

The calibration for this section follows the same strategy as before. Targets and moments implied by the model are shown in Table 2. The model with the working capital constraints does slightly better in many aspects, in particular in terms of the volatility of net exports to output ratio as it has an extra free parameter, the share of the wage bill that has to be advanced before production takes place, as explained later. The model implies that about one third of the wage bill has to be paid in advance. This estimate is actually much smaller than the calibration and the findings in the existing literature. The reason for this calibration relies on the fact that our model has in the firm dynamics an already strong amplification device. The calibrated parameters are shown in the fourth column in Table 3. As can be seen, even though the working capital constraint coefficient is not large, it affects the parameterization of the stochastic processes. In particular, the size of average volatility of spread shock increases, as well as the standard deviation of its volatility. The reason for this is that now interest rate shocks have a direct impact on the supply side of the economy. Figure 4 presents the impulse response functions for the model with endogenous markups using the solid lines and without endogenous markups using the dashed lines.

As seen in the figure, endogenous markups play a role similar to that in previous variants of the model. Here, the calibration implies that the impact of volatility shocks is larger than without working capital constraints. This is reasonable as working capital constraints induce a direct effect of the stochastic process of spread in the labor demand. Additionally, allowing for endogenous markups amplifies the response of output and hours by a factor of 3. Similar effects are observed in the dynamics of investment and consumption.

6. MARKUPS AND VOLATILITY OVER THE BUSINESS CYCLE

This section explores the empirical relationship between markups, firm dynamics, and a measure of volatility over the business cycle in small open economies. I use industrial and spreads data from various small open economies, and I show that markups and volatility tend to be positively correlated, countercyclical, and strongly volatile in small open economies. Then, I study the firms' entry and exit as one of the potential sources of markups variability. The findings in this section provide supporting evidence of firm dynamic playing an amplification role for volatility shocks through time-varying markups.



NOTES: This figure plots the response to a 1 std shock to the volatility of spread shock. The impulse response function for variable x is plotted as $100 \times \hat{x}$, where \hat{x} denotes the log deviations. Impulse responses are constructed using the generalized impulse response function.

FIGURE 4

IMPULSE RESPONSE TO A SPREAD VOLATILITY SHOCK WITH WORKING CAPITAL CONSTRAINTS [COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

This section uses the UNIDO Indstat2 database, which contains harmonized annual data from 1963 to 2010 for various economies around the world. Additionally, I also use GDP for each economy from the World Development Indicator database from the World Bank measured in dollars at fixed 2005 prices. There has been extensive controversy on the appropriate measure of markups in the data given that marginal costs are not directly observed. As discussed in Braun and Raddatz (2012), markups can be derived from the labor margin. I compute markups in the data using the inverse of labor wages to value added $Mk_t = \frac{VA_t}{W_t}$, where W_t denotes total wages for the 28 industries at 2-digit level ISIC Revision 3 and VA_t denotes total value added for these industries.

Table 6 presents markups volatility and its correlation with GDP in various small open economies around the world in percentage terms. Markups, volatility, and GDP are detrended accordingly. As seen in the table, the volatility of markups substantially depends on the specific country we study, but overall, the variability of markups is strong, which would suggest it can potentially be an important variable to take into account when studying the impact of different aggregate shocks. A second question is about the behavior of markups over the business cycle; the second column in the table shows that there are significant differences in the sign of the correlation as well as in sizes between different economies. However, on average, correlation

TABLE 6
MARKUPS AND THE BUSINESS CYCLE

Country	$\sigma(mk)$	$\rho(mk, gdp)$
Argentina	20.3 (4)	-55.4 (12.5)
Bolivia	37.4 (5.6)	-40.2 (6.9)
Chile	19 (2.9)	-46.7 (8.1)
Colombia	9.5 (1.3)	-18.8 (2.7)
Korea	9.7 (1.3)	-46.5 (6.8)
Ecuador	38.8 (5)	-51.7 (7.3)
Greece	8.6 (1.3)	-3.1 (0.5)
Israel	17.3 (2.3)	7.9 (1.1)
Mexico	11.3 (2.5)	-35.1 (8.5)
Peru	14.9 (3.4)	-28 (7.1)
South Africa	13.6 (1.8)	7.9 (1.2)
Turkey	29 (3.3)	8.2 (1.2)
Venezuela	31.3 (4.7)	-21.2 (3.5)
Average	20.1	-24.8

NOTES: $\sigma(mk)$ is the log-markups volatility with linear detrending. $\rho(mk, gdp)$ is the contemporaneous correlation between markups and GDP both in logs and linearly detrended. All moments are in percentage. Details on data sources and management are available in the online appendix.

is negative. This implies that there is evidence that markups are significantly countercyclical in many emerging economies at annual frequency. This is important because, even though there has been substantial discussion regarding markups in the United States, there is less evidence on markups behavior for the rest of the world.

About the comovement between spreads volatility and markups, the model implies that volatility shocks tend to increase markups over time. To study this in the data, I estimate spread volatility using monthly series of Emerging Markets Bond Index+ (EMBI+) for various emerging economies using the following model:¹³

$$s_t = \rho_s s_{t-1} + \sigma_s e^{v_{s,t}} \epsilon_{s,t},$$

where

$$v_{s,t} = \rho_{v,s} v_{s,t-1} + \sigma_{v,s} \eta_{s,t}.$$

Here s_t denotes demeaned annualized spreads at monthly frequencies, the estimation is implemented with a Gibbs Sampler in line with the procedures in Garcia Cicco et al. (2012) and Seoane (2015b) using 25,000 draws, and I keep the second half for posterior distributions. I set priors as given in Table 7.

Smooth estimates of volatility, displayed as $\exp(v_{s,t})$, are shown in Figure 5. As seen in the figure, there seems to exist ample evidence of time-varying volatility of spreads in the data. In most of the cases, volatility increases during the late 1990s and early 2000s and peaks again at the beginning of the financial crisis in 2008.

I want to use smoothed estimates of volatility to inquire about the correlation between time-varying volatility with markups, which are available at an annual frequency. To compute these correlations, I construct annual aggregates of volatility by taking annual averages of the smooth estimates of $v_{s,t}$. Contemporaneous and lagged correlations are shown in Table 8.

¹³ Notice that this measure of spreads abstract from the debt elastic interest rate channel presented in the model. This is done for simplicity; however, the variability of the interest rate channel in the model is very small. In particular, for the baseline calibration, the variability of a measure of interest rate without the debt elastic channel will be only 2% larger than the variability of the interest rate including the debt elastic interest rate channel, as defined in the baseline model.

TABLE 7
PRIOR DISTRIBUTIONS

Parameter	Distributions
ρ	$N(0.9, 0.001)$
$\begin{bmatrix} \tilde{\sigma}(1 - \rho^\sigma) \\ \rho^\sigma \end{bmatrix}$	$N(\begin{bmatrix} -0.25 \\ 0.9 \end{bmatrix}, \begin{bmatrix} 5 & 0.00025 \\ 0.00025 & 2.5 \end{bmatrix})$
η	$IG(10, 2)$

NOTES: $N(x, y)$ denotes a normal distribution with mean x variance y . The priors for autocorrelation coefficients are truncated normal in the interval $(0, 1)$. $IG(x, y)$ denotes an inverse gamma distribution with degrees of freedom x and scale matrix y .

TABLE 8
MARKUPS AND THE LOG OF VOLATILITY OF SPREADS

Country	$\rho(mk_t, sv_t)$	$\rho(mk_t, sv_{t-1})$	$\rho(mk_t, sv_{t-2})$
Argentina	34.7	75.1	23.7
Colombia	-64.8	-61.3	-37.3
Ecuador	46	43.6	-20.8
Mexico	12.2	57.9	49.5
Turkey	74.3	54.7	53.8
Average	20.5	34	13.8

NOTES: mk_t denotes the log-markups and sv_t denotes the log stochastic volatility. $\rho(mk_t, sv_t)$ is the contemporaneous correlation between markups and stochastic volatility whereas $\rho(mk_t, sv_{t-j})$ is the correlation between markups and j order lags of log volatility. All moments are in percentage. Details on data sources and management are available in the online appendix.

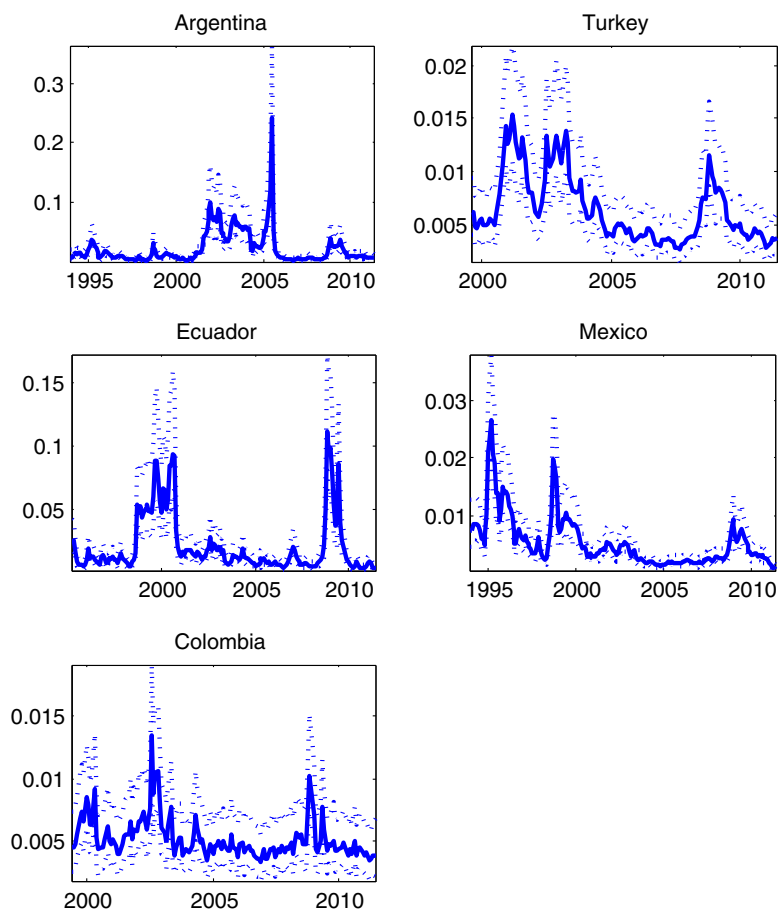
As seen in the table, the data seem to suggest there is a positive contemporaneous correlation, but, importantly, in line with the model, it seems to suggest that dynamic correlations are also positive for different lags of spreads. This means, for instance, that increases in spread volatility one or two years lagged tend to be positively related to markups in the future. This evidence is in line with the impulse responses computed in the model where increases in spreads volatility tend to trigger over time an increase of markups. Figure 6 presents related evidence; as seen in the figure, the samples used to compute correlations as well as the figures are small, and, hence, evidence should be considered as stylized but nonetheless informative.

6.1. Firm Dynamics as an Amplification Device. Firm dynamics is likely to be a potential amplifier for markups' variability. This is shown for the United States by Jaimovich and Floetotto (2008). A mechanism might operate in the following way: When firms enter competition increases, which drives markups down, and the opposite occurs when firms exit. In this case, firms are procyclical and induce countercyclical markups. This section presents basic but suggestive evidence on firm dynamics and GDP growth. Specifically, Table 9 computes the correlation between net entry and exit of firms and GDP growth using annual data from Bartelsman et al. (2009).¹⁴

The table shows the percentage correlation between rate of net firms entry and GDP growth. As seen in the table, there is strong evidence suggesting that net entry of firms is procyclical. As can be seen, however, standard errors are large, which occurs because of short sample.

In other words, Table 9 is in line with the mechanism described earlier and suggests that firms tend to enter during good times and tend to exit during bad times. Moreover, the expansion seems to be characterized by a drop in markups, whereas the contraction tends to occur with an increase in markups. The empirical analysis of this section relies on looking at correlations

¹⁴ Data are available at <http://econweb.umd.edu/~haltiwan/download.htm>.



NOTES: Spread volatility at monthly frequency for various emerging economies with 16th and 84th percentiles. Computed using monthly series of EMBI+ at annual levels.

FIGURE 5

EMBI+ VOLATILITY OF SPREADS [COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

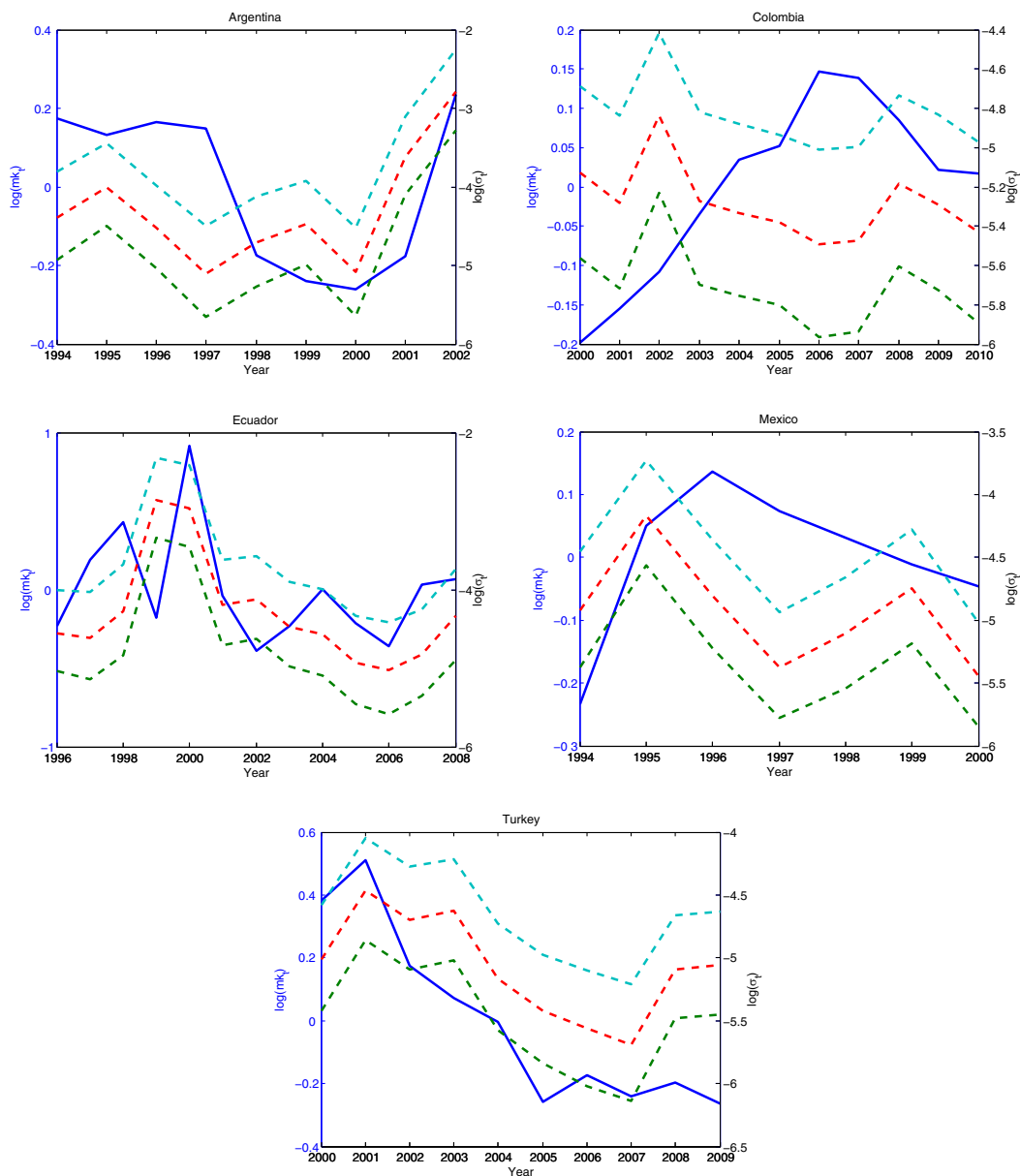
TABLE 9
FIRM DYNAMICS AND THE GROWTH RATE OF GDP

Country	Correlation	St. Err.
Argentina	87.6	35.7
Brazil	69	34.5
Chile	40.5	9.3
Colombia	22.7	5.9
Mexico	15.2	3.9
Portugal	31.1	8

NOTES: Correlation between firms entry share net of firms exit share and GDP growth in percentage. Details on data sources and management are explained in the data appendix.

for different small open economies, and, of course, it does not impose any particular direction for the causality. However, it provides strong evidence that supports the plausibility of the mechanism behind the theoretical model.¹⁵

¹⁵ This evidence does not intend to rule out other drivers of markups variability such as, for instance, price stickiness. Instead, the evidence in this section suggests that on top of price stickiness, there might be a role for firm dynamics to amplify the response of markups to exogenous disturbances.



NOTES: Data are computed using EMBI+ and UNIDO Indstat. The left axis measures demeaned log markups in lines whereas the right axis measures annual average of log volatility in dashed lines together with the annual averages of the 16th and 84th percentiles.

FIGURE 6

SPREAD VOLATILITY AND MARKUPS [COLOR FIGURE CAN BE VIEWED AT WILEYONLINELIBRARY.COM]

7. CONCLUSIONS

This article studies the role of time-varying markups in the amplification of volatility shocks in real models. Specifically, it shows that the existence of endogenous time-varying markups amplifies the response of hours, consumption, investment, and output compared to the model with fixed markups. This is indeed the main contribution of this article given that time-varying markups have so far only been studied using sticky prices models, where it is not possible to isolate the effects of markups from those of sticky prices. Conversely, this article shows that

pure markup effects can substantially affect the quantitative responses of endogenous variables to volatility shocks.

To study the role of time-varying markups in a pure real economy the model assumes monopolistic competition as in Jaimovich (2007), which generates entry and exit of firms and gives rise to countercyclical markups as firm dynamics affects the degree of competition. This model, hence, allows us to study the role of endogenously time-varying markups without assuming either price frictions or nominal disturbances and, consequently, allows us to isolate the effects of markups from those of nominal frictions, something that is impossible in New-Keynesian sticky prices models.

I show that endogenous time-varying markups amplify the responses of endogenous variables to a volatility shock because it exacerbates the impact of volatility shocks on the real wage. Specifically, an increase in volatility triggers a consumption drop because of precautionary savings motives. Additionally, it negatively affects investment because it makes investment returns more risky. These two effects decrease the demand side of the economy. In the open economy, the trade balance improves, imports drop, and the domestic economy increases savings in foreign debt. Given the assumptions of monopolistic competitive firms, the drop in demand forces the exit of firms, which lowers the degree of competition and drives markups up. The increase in markups operates as inducing a drop in the technology and decreases the real wage inducing a drop in labor supply. The joint drop in labor and technology through the increase in markups induces an extra negative impact on output, which subsequently reinforces the drop in demand. This channel is absent without time-varying markups. These findings are robust to different degrees of Frisch elasticity, adjustment costs, spreads elasticity, and utility functions. Moreover, these findings are robust to alternative ways of modeling endogenously time-varying markups. For instance, the online appendix shows that if markups are time varying because of the existence of deep habits as in Ravn et al. (2006), the same type of amplification is observed.

One of the main implications of this article is that the use of a real model might underestimate the impact of volatility shocks as long as it does not consider the existence of time-varying markups.

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Online Appendix

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